

# RETRIEVING ATMOSPHERIC TEMPERATURE AND MOISTURE PROFILES FROM NPP CRIS/ATMS SENSORS USING CRIMSS EDR ALGORITHM

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## 1. INTRODUCTION

The Joint Polar Satellite System (JPSS) is a U.S. National Oceanic and Atmospheric Administration (NOAA) mission in collaboration with the U.S. National Aeronautical Space Administration (NASA) and international partners. The NPP Cross-track Infrared Microwave Sounding Suite (CrIMSS) consists of the infrared (IR) Cross-track Infrared Sounder (CrIS) and the microwave (MW) Advanced Technology Microwave Sounder (ATMS). The CrIS instrument is hyperspectral interferometer, which measures high spectral and spatial resolution upwelling infrared radiances. The ATMS is a 22-channel radiometer similar to Advanced Microwave Sounding Units (AMSU) A and B. It measures top of atmosphere MW upwelling radiation and provides capability of sounding below clouds. The CrIMSS Environmental Data Record (EDR) algorithm provides three EDRs, namely the atmospheric vertical temperature, moisture and pressure profiles (AVTP, AVMP and AVPP, respectively), with the lower tropospheric AVTP and the AVMP being JPSS Key Performance Parameters (KPPs). The operational CrIMSS EDR algorithm was originally designed to run on large IBM computers with dedicated data management subsystem (DMS). We have ported the operational code to simple Linux systems by replacing DMS with appropriate interfaces. We also changed the interface of the operational code so that we can read data from both the CrIMSS science code and the operational code and be able to compare lookup tables, parameter files, and output results. The detail of the CrIMSS EDR algorithm is described in reference [1]. We will present results of testing the CrIMSS EDR operational algorithm using proxy data generated from the Infrared Atmospheric Sounding Interferometer (IASI) satellite data and from the NPP CrIS/ATMS data.

## 2. DESCRIPTION OF THE CRIMSS EDR ALGORITHM

In order to retrieve atmospheric temperature, water, and trace gas vertical profiles from these high spectral resolution data, one has to account for cloud radiative contributions to the top of atmospheric (TOA) radiance

spectra. The CrIMSS EDR algorithm uses a cloud-clearing (CC) method, which combines the information content of both MW and IR, to retrieve the KPPs.

The cloud-cleared radiance  $\hat{R}_{i,clr}$  for channel  $i$  can be expressed as a linear combination of the measured radiances

$$\hat{R}_{i,clr} = \bar{R}_{i,1} + \eta_1(\bar{R}_{i,1} - \bar{R}_{i,k+1}) + \dots + \eta_k(\bar{R}_{i,1} - \bar{R}_{i,2}) \quad (1)$$

Where  $\mu_k$  are unknown channel-independent constants,  $\bar{R}_{i,k}$  are the measured radiances for the field of view  $k$ . At least  $k+1$  field of views (FOV) are needed to solve for  $k$  cloud formations. Since MW radiances are less affected by the presence of clouds relative to IR radiances, the CrIMSS algorithm first performs MW only retrieval to get a first guess for the atmospheric temperature and moisture profiles and surface skin temperature. The MW retrieval outputs are then used by the CrIMSS IR forward model to calculate an estimate for  $\hat{R}_{i,clr}$ . We then solve equation (1) to obtain the values for  $\mu_k$ . It should be mentioned that only a few selected CrIS spectral channels are used in this process so that the uncertainties in the surface radiances will not affect the values of  $\mu_k$ . Once the values for  $\mu_k$  are obtained, equation (1) is used to calculate the cloud-clear radiances for the whole CrIS spectrum.

A maximum likelihood method is then used to retrieve CrIMSS EDRs. The inversion algorithm is based on an iterative method with climatology covariance and a priori information as constraints:

$$X_{n+1} - X_a = (K^T S_y^{-1} K + S_x^{-1})^{-1} K^T [(y_n - Y_m) + K(X_n - X_a)] \quad (2)$$

where  $x$  represents state vector, the subscripts  $n$  and  $a$  represent iteration number and a priori, respectively.  $K$  is the Jacobian matrix.  $Y_m$  is the measured ATMS and the cloud-cleared CrIS radiances.  $Y_n$  is the forward model calculated radiances using the state vector obtained from the  $n$ th iteration.  $S_y$  and  $S_a$  are error covariance matrices associated with observation (including forward model errors) and background state vector, respectively. All relevant parameters such as atmospheric profiles and surface properties are retrieved simultaneously. Once the improved state vectors are obtained, the CrIMSS algorithm iteratively improves cloud clearing parameters and state vectors using both equation (1) and (2).

In the current version of the CrIMSS algorithm, 9 FOVs are used to perform cloud clearing. The spatial resolution of the EDR product is about 45 km at Nadir. We have test the CrIMSS algorithm performance by using proxy data from the IASI/AMSU/MHS observations. The details will be given in the result section.

### 3. RESULTS

The IASI on board the METOP-A satellite provides all the information needed to generate CrIS proxy data. The IASI instrument is a Fourier Transform Spectrometer (FTS) with a spectral sample interval of  $0.25 \text{ cm}^{-1}$  and a continuous spectral coverage from  $645$  to  $2760 \text{ cm}^{-1}$  [3]. The CrIS instrument has three spectral bands with spectral coverage of  $648.75 - 1096.25 \text{ cm}^{-1}$ ,  $1207.5 - 1752.5 \text{ cm}^{-1}$ , and  $2150.0 - 2555.0 \text{ cm}^{-1}$ , respectively [1]. The transformation from an IASI radiance spectrum to a CrIS proxy spectrum is a rigorous mathematical operation [2]. The generated proxy data have been successfully ingested into the CrIMSS OPS code. This data set is very useful for algorithm testing and validation because it provides realistic scenes (atmosphere, surface and cloud), which are based on observations. It helps us to identify areas of deficiencies in both forward and inverse models, testing robustness of the operational code, check error handling capability of the OPS code. It enables us to perform bias characterization, algorithm tuning, and EDR performance evaluations. Figure 1 shows the CrIMSS retrieval results using the IASI proxy data. The retrieved 500 mbar temperature values compare well with ECMWF forecast field. The algorithm will be applied to the NPP CrIS data as soon as it becomes available.

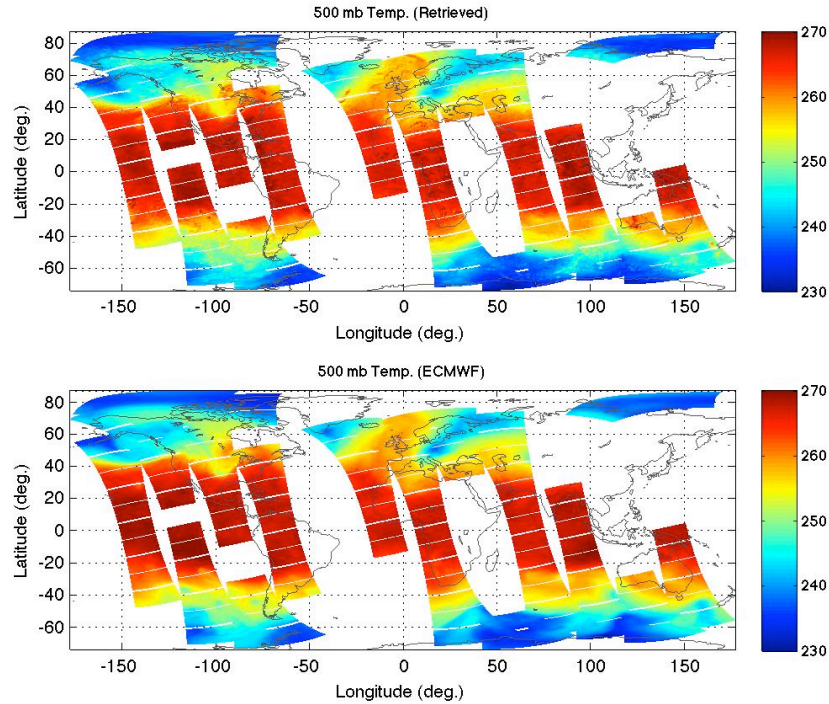


Figure 1: Top panel: retrieved 500 mb temperature from the CrIMSS algorithm, bottom panel: ECMWF 500 mb temperature field

#### 4. CONCLUSIONS

Before the CrIS data become available from the NPP satellite, we have tested and tuned the CrIMSS operational code using proxy data generated from the IASI spectra. Results show that the CrIMSS EDR algorithm works well

with the proxy data. Since the transformed IASI spectral provide very good proxy data for the CrIS instrument, we expect that the CrIMSS algorithm will perform well when the CrIS data becomes available.

## 11. REFERENCES

- [1] Northrop Grumman Space Technology, “Cross Track Infrared Sounder (CrIS) Volume II, Environmental Data Records (EDR) Algorithm Theoretical Basis Document ATBD”, Northrop Grumman Space Technology, Redondo Beach, CA, Feb. 8, 2007.  
[http://jointmission.gsfc.nasa.gov/science/sciencedocuments/072010/D43772\\_Rev%20C\\_CrIS\\_CrIMSS\\_ATBD\\_Final\\_Dist%20ECR%20A-120A\\_Statement%20A%20Submission.pdf](http://jointmission.gsfc.nasa.gov/science/sciencedocuments/072010/D43772_Rev%20C_CrIS_CrIMSS_ATBD_Final_Dist%20ECR%20A-120A_Statement%20A%20Submission.pdf)
- [2] X. Liu, and S. Kizer, “Testing CrIMSS EDR Algorithm Using Synthetic and Proxy Data”, Sounder Operational Algorithm Team (SOAT) Meeting, Logan, UT, September 10, 2009. [ftp://www.star.nesdis.noaa.gov/pub/smcd/spb/nnalli/SOAT/200909/090910-soat\\_04\\_04\\_liu.pdf](ftp://www.star.nesdis.noaa.gov/pub/smcd/spb/nnalli/SOAT/200909/090910-soat_04_04_liu.pdf)
- [3] EUMETSAT, “IASI Level 1 Product Guide”, EUM/OPS-EPS/MAN/04/0032, Issue v3, May 13, 2009

**Biography:** Dr. Xu Liu is currently a senior research scientist in the Chemistry and Dynamics Branch of the Science Directorate at NASA Langley Research Center. He has developed algorithms for radiometric calibration, instrument line shape characterization, fast radiative transfer models, and atmospheric parameter retrievals for various instruments ranging from microwave to visible spectral range. He served as members on various government teams and performed collaborated work with international partners on remote sensing. He developed a super fast Principal Component-based Radiative Transfer Model (PCRTM), which has been successfully applied to hyperspectral sensors such as NAST-I, IASI, AIRS, and CLARREO. He was the key author for the NPOESS CrIMSS EDR algorithm and the ATBD. Dr. Xu Liu has received numerous awards such as National Science Foundation Antarctic Service award, NASA superior accomplishment award, NASA performance award, NASA inventions and contributions board awards, and NASA Exceptional Achievement Medal.